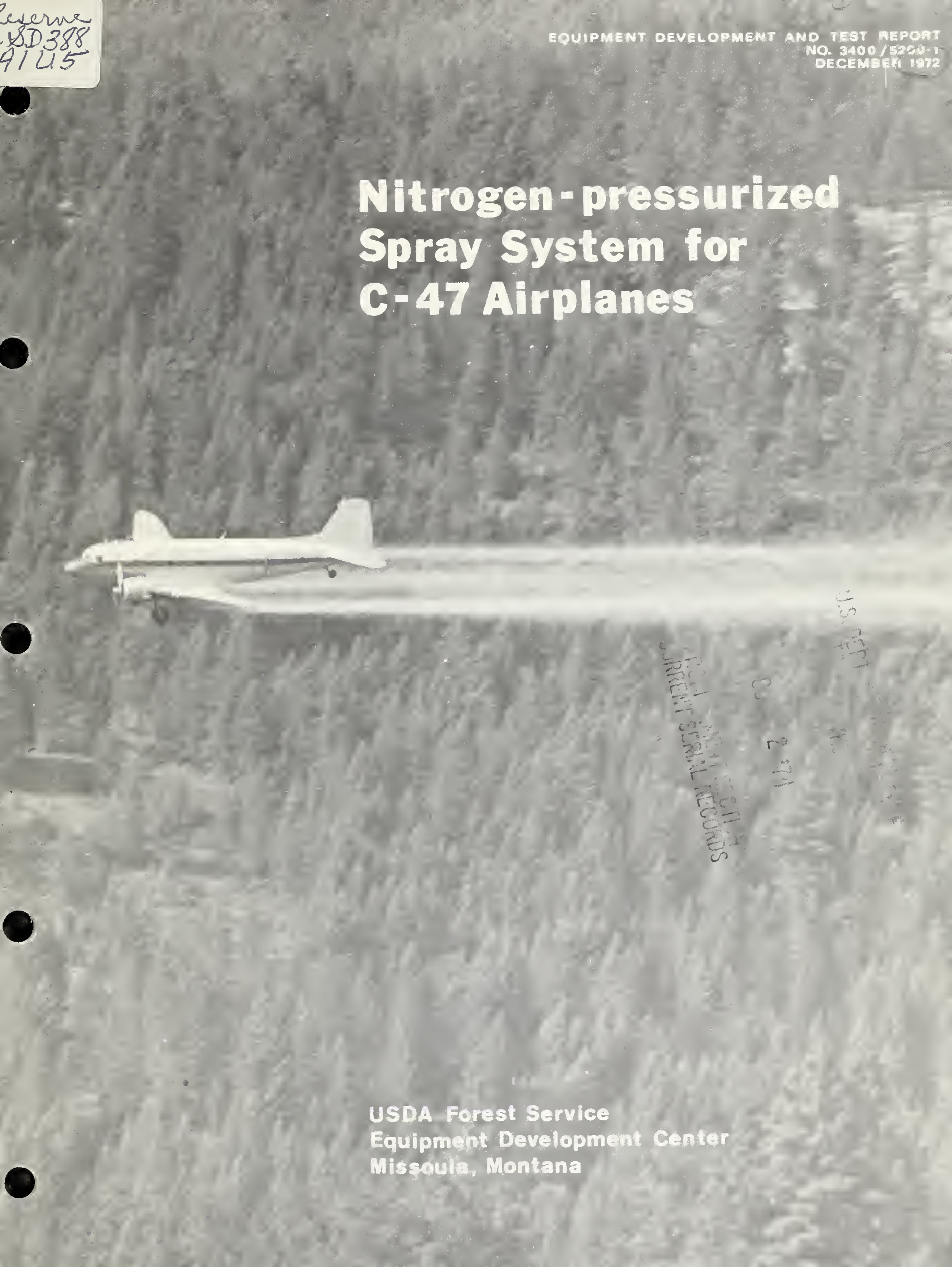
EQUIPMENT DEVELOPMENT AND TEST REPORT
NO. 3400/5200-1
DECEMBER 1972

Nitrogen-pressurized Spray System for C-47 Airplanes



USDA Forest Service
Equipment Development Center
Missoula, Montana

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Use Pesticides Safely
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U.S. DEPARTMENT OF AGRICULTURE

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NITROGEN-PRESSURIZED SPRAY SYSTEM FOR C-47 AIRPLANES

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ACKNOWLEDGEMENTS

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Insecticide Evaluation Project, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. (Assistance on insecticide formulation and spray assessment.)

Region 1, Division of State and Private Forestry, Forest Insect and Disease Branch, Missoula, Montana. (Spray project coordination, biological assessment of the insects.)

U. S. Army, Deseret Test Center, Fort Douglas, Utah. (Evaluation of C-47 Spray System.)

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ABSTRACT

A nitrogen-pressurized spray system for applying insecticides from C-47 airplanes has been developed. The system is operated by using gaseous nitrogen to expel from the spray tank either (1) a conventional insecticide solution which emerges with a droplet spectrum having a mass median diameter (mmd) of 120 microns; or (2) a solution 50 percent insecticide and 50 percent Freon 12, which emerges with a droplet spectrum having a mmd of 60 microns. The system has performed satisfactorily on three pilot tests using Zectran for controlling spruce budworm (*Choristoneura* sp.) in Montana and Idaho. Advantages over systems that utilize pumps to expel the insecticide are simplicity, reliability, ease of installation, and reduced danger of leaks and fire. Construction drawings may be obtained from the Missoula Equipment Development Center.

A report on ED&T Project No. 1541 — Aircraft Spray Systems — sponsored by the Division of Forest Pest Control.

INTRODUCTION

In 1964, the U.S. Forest Service established an Insecticide Evaluation Project (IEP) at the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., with the objective of developing insecticides for controlling destructive forest insects with a minimum of environmental impact. In 1965, the Division of Forest Pest Control requested the Missoula Equipment Development Center to provide special equipment required by the IEP. At the time, the IEP was conducting large-scale pilot tests using Zectran[1] against the spruce budworm (*Choristoneura* sp.) in Montana and Idaho. Spraying was done with commercial systems that produced a spectrum of drops up to 360 microns in diameter, with a mass median diameter [2] (mmd) of 160 microns.

After several pilot tests had been completed, IEP researchers wanted to explore two hypotheses: (1) that the smaller droplets (under 100 microns) in the spectrum were more lethal than the larger ones, which were seldom found on the dead budworm larvae and (2) that an aerosol of fine droplets released under proper atmospheric conditions would be disseminated throughout the target area by natural air movements as effectively as swath spraying. No commercial spray system available would produce droplets below 100 microns in diameter at the high flow rates required to cover thousands of acres comprising the pilot tests.

Development work on a spray system to meet these needs was begun in 1966. A prototype was flown on tests in Idaho in 1967. Improved models were flown on tests in Montana in 1968 and in Idaho in 1969 and 1971. Design was finalized in 1971 and has been certified by the Federal Aviation Administration (FAA).

The spray system utilizes nitrogen under pressure to propel the insecticide solution out of the spray tank and through the nozzles. Using nitrogen alone as a propellant will produce a droplet spectrum comparable to conventional commercial systems – droplets up to 350 microns in diameter, with an mmd of 120 microns. Adding Freon 12[3] to the insecticide solution at the rate of 1:1 (weight) will produce a spectrum with droplets no larger than 120 microns and an mmd of 60 microns. The spray system will produce 60 micron mmd droplets at high flow rates – up to 92 gallons per minute.

Expelling the insecticide with nitrogen rather than with a pump driven by a windmill, gasoline engine, hydraulic motor, etc., has many advantages. Gasoline engines introduce the hazard of noxious, explosive fumes. Pumps often leak around seals and contaminate the aircraft with insecticide. Because of its simple design, the nitrogen system is easy to install and operate, and it is reliable.

This report describes the nitrogen-pressurized spray system, installation, operation, performance, and procurement. The system is not available commercially. However, most parts are stock items, or can be readily fabricated, except the tank. The tank can be manufactured by metal fabricators equipped to build aluminum pressure vessels to the ASME code.

The system costs about $10,000 to build. Construction drawings can be obtained from this Center.

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1 Zectran, 4-dimethylamino-3, 5-xylyl methylcarbamate ($C_{12}H_{18}N_2O_2$) Dow Chemical Co., Midland, Mich.

2 mmd, 50 percent of the spray volume being in drop sizes larger than 160 microns and 50 percent of the spray volume in drop sizes below 160 microns.

3 Freon 12, dichlorodiflouromethane (CCl_2F_2) E. I. Du Pont Co., Wilmington, Del.

DESCRIPTION OF SPRAY SYSTEM

The spray system (fig. 1) consists of the following components: spray tank, boom, nozzles, nitrogen cylinders, regulators, control panel, and dump system. A brief description of each component follows.

Spray tank.—The aluminum spray tank (fig. 2) is designed and fabricated to meet the ASME Unfired Pressure Vessel Code requirements for a working pressure of 100 psig at a temperature of 100°F. It is 13 ft 9 in. long, 36 in. in diameter and holds 700 U.S. Gallons. The tank, its supports, and the attached plumbing and valves weigh approximately 1,100 lb empty. Baffles inside the tank prevent the insecticide solution from rapidly shifting and adversely affecting flying characteristics of the airplane.

When filled with the heavier solution, Freon 12-Zectran, the combined weight of the tank, solution, and accessories is 7,600 lb. Five padded bunks under the tank distribute the load to the floor beams, which have a design load of 3,500 lb each (McDonnell Douglas Corp.). The forward and rearward bunks are attached and can be raised on retractable casters to facilitate positioning the tank.

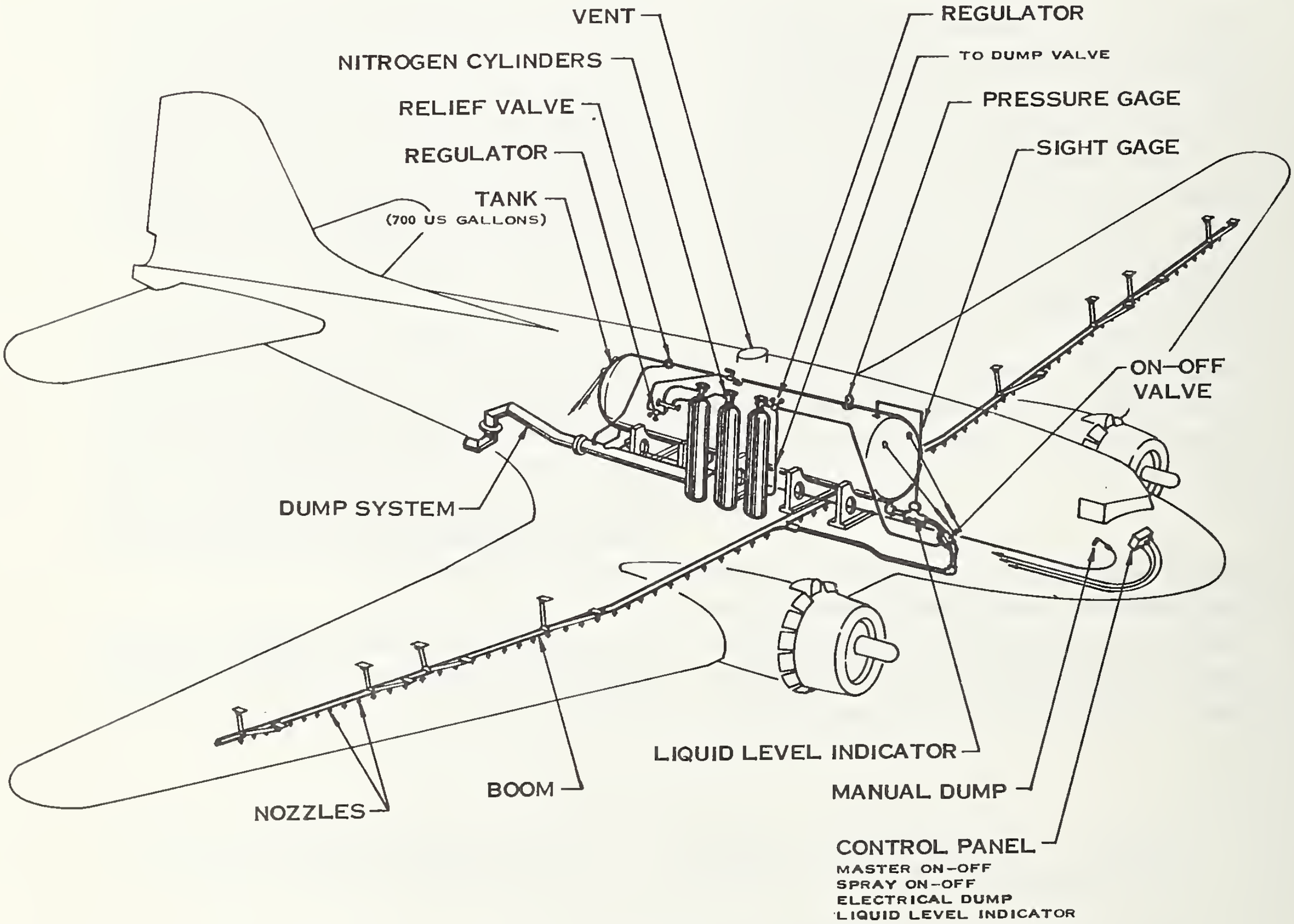

Figure 1.—Nitrogen-pressurized spray system installed in C-47 airplane.

The complete system is designed to withstand a 9-G impact load as prescribed by FAA regulations. The tank is secured to the floor by twelve tiedowns using 3/16-in. diameter, 7 x 19 aircraft cable with a breaking strength of 4,200 lb. Twelve tiedown attachment points, four on each side, two on each end, are provided on the tank.

Boom.—The spray boom is 65 feet long with 250 1/8-in. NPT threaded holes spaced at 3-inch intervals. The boom is made of an aluminum alloy to minimize weight and is extruded to an airfoil shape to reduce drag. It consists of a center section and two wing sections. Each wing section has four brackets for fastening the boom to the wing. Three of these can be seen on the portion of the outboard boom section shown in figure 3.

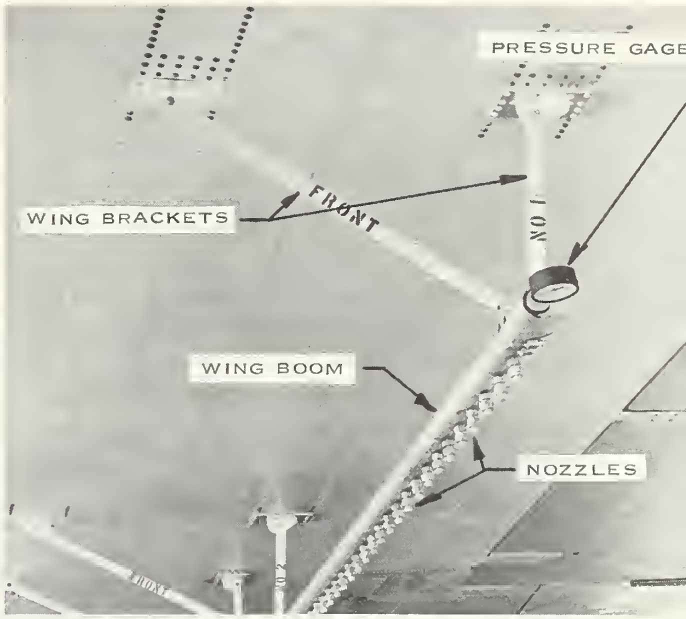

Figure 3.—Outboard boom section. (pressure gage has been installed for ground testing.)

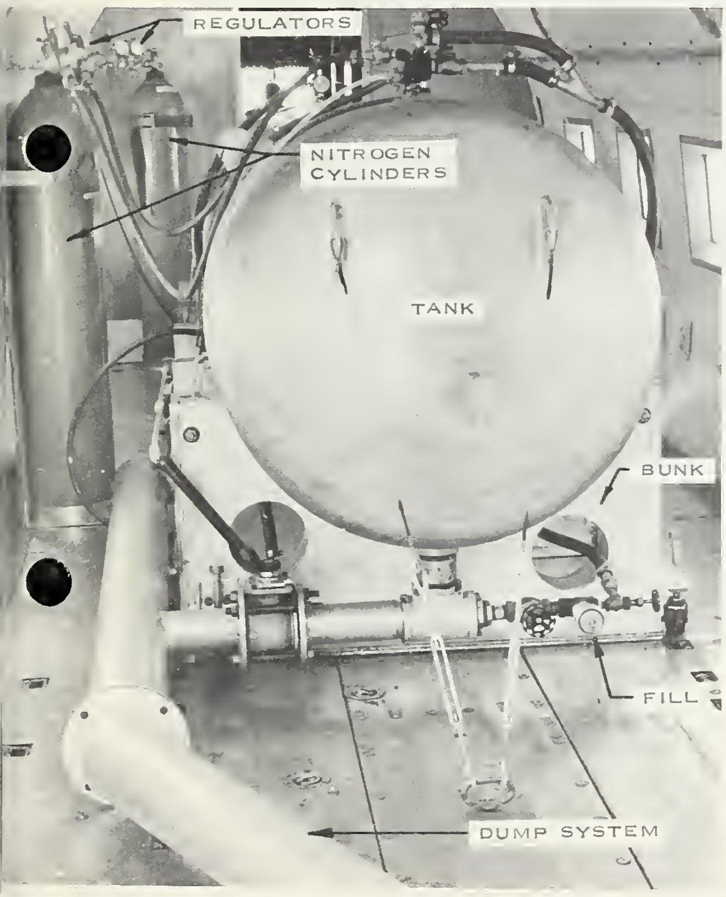

Figure 2.—An early model of the nitrogen-pressurized spray system viewed from rear of airplane.

Nozzles.—The nozzle selected and the number of nozzles fitted to the boom are dictated by the flow rate, droplet size, and spray pattern desired. Detailed specifications, performance data, and instructions for calculating flow rates are provided by nozzle manufacturers. Two-hundred and fifty TX-26 nozzles made by Spraying Systems Co., Wheaton, Ill., were used in the nitrogen-Freon 12 tests and 104 number 8015 Spraying Systems Co. nozzles were used in the nitrogen-conventional solution tests.

Nitrogen cylinders.—The spray tank is pressurized with nitrogen supplied by two 300 standard cubic foot (scf) 2,400 psi cylinders. Gas from a third nitrogen 300 scf cylinder actuates the electrically triggered tank-to-boom valve and the two emergency dump valves. Nitrogen was selected because it is inexpensive, inert, and readily available from industrial gas suppliers.

Regulators.—Operating pressure of the spray system is controlled by high-pressure regulators at the nitrogen cylinders. Pressure gages at the tank indicate the pressure maintained in it, and a pressure gage located on the forward bulkhead of the cargo compartment indicates the boom pressure.

Control panel.—The spray system controls are located on a panel attached to the cockpit console within reach of the pilot or copilot (fig. 4). A master switch with an indicator light controls electrical input to the system. The spray control switch activates a valve in the feed line between the tank and boom. This valve is triggered electrically and is actuated by nitrogen gas.

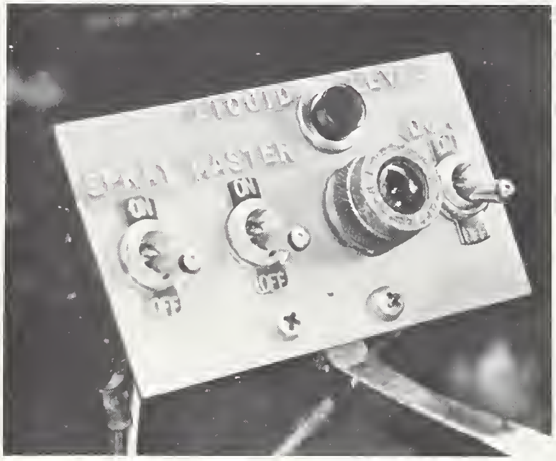

Figure 4.—Spray system control panel. (The dump switch protective cover is not shown so switch is visible.

An indicator light on the panel comes on automatically when the spray tank is empty. In an emergency a "dump" switch on the panel can be activated to empty the tank. The emergency switch has a protective cover to prevent accidental dumping of the tank.

Emergency dumping system.—The contents of the spray tank can be dumped through a 6-inch diameter pipe that leads outside the airplane. The dump pipe is connected to two 3-inch tank outlets controlled by ball valves that can be triggered electrically or mechanically by pull cable from the cockpit.

Vent.—To insure that no fumes collect inside the airplane if a leak occurs, a vent is installed above the tank. The vent is 6 in. in diameter, extends through the fuselage, and slopes 15 degrees toward the tail. Air passing over the outside opening causes a low pressure in the duct and draws vapor out of the cargo compartment.

The spray system can be installed in a C-47 with a minimum of modifications. The spray tank is lifted into the fuselage through the cargo doors and rolled into position on retractable casters. The three remaining bunks are slipped under the tank and leveled with metal shims until the padding on each cradle is evenly compressed, indicating that the load is evenly distributed.

The boom sections are bolted to existing nutplates on the airplane and to existing joints on the wing and fuel tank cover (fig. 5). Nitrogen cylinders are strapped to a stand that is secured to a bulkhead in the fuselage. The control panel is attached to the cockpit console with metal screws.

Plumbing is installed with ordinary pipefitting tools, and a hose clamp is used to secure the tank-to-boom line. The only modifications required to the airplane are cutting two 6-inch holes in the skin for the dump system and fuselage vent, and a 2½-inch hole for the tank-to-boom line. The aluminum skin around the 6-inch holes must be reinforced by installing doublers. Once these minor modifications have been made, the spray system can be installed or be removed easily.

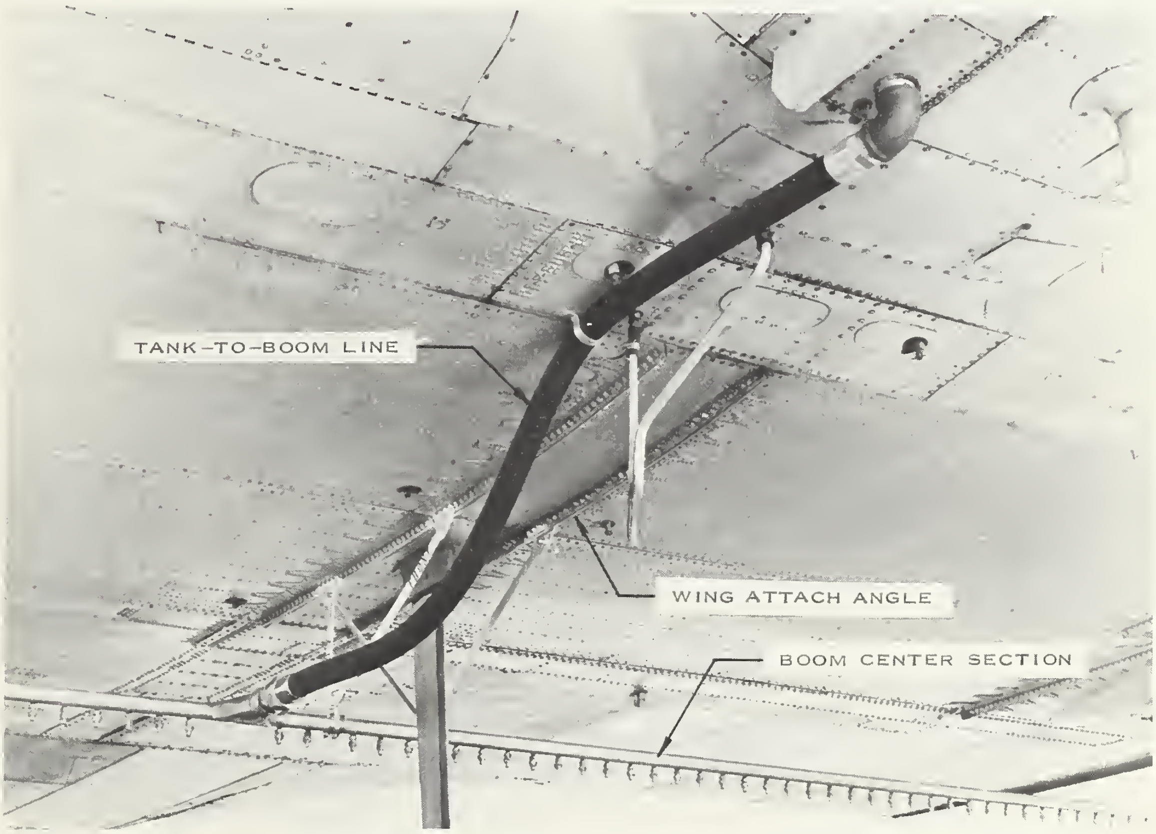

Figure 5.—Aft view showing center boom section bolted to existing fuel tank cover attach angles.

Figure 6 presents a simplified diagram of the spray system. Prior to filling the tank, all switches on the control panel are placed in the "off" position and all manual valves are closed. The tank is filled with conventional insecticide or insecticide-Freon 12 solution through the fill opening. When the desired level is registered on the tank sight gage, the fill valve is closed. The valves on the nitrogen cylinders are opened, and the regulators are adjusted until the desired pressure is indicated on the pressure gage. For a conventional insecticide solution, spray tank pressure should be 40-60 psi. If Freon 12 is added to produce finer droplets, tank pressure must be maintained at 75 psi to keep the Freon 12 in liquid form. The system has been designed to withstand an operating pressure of 100 psi. The manual valve in the nitrogen cylinder-to-tank line is opened.

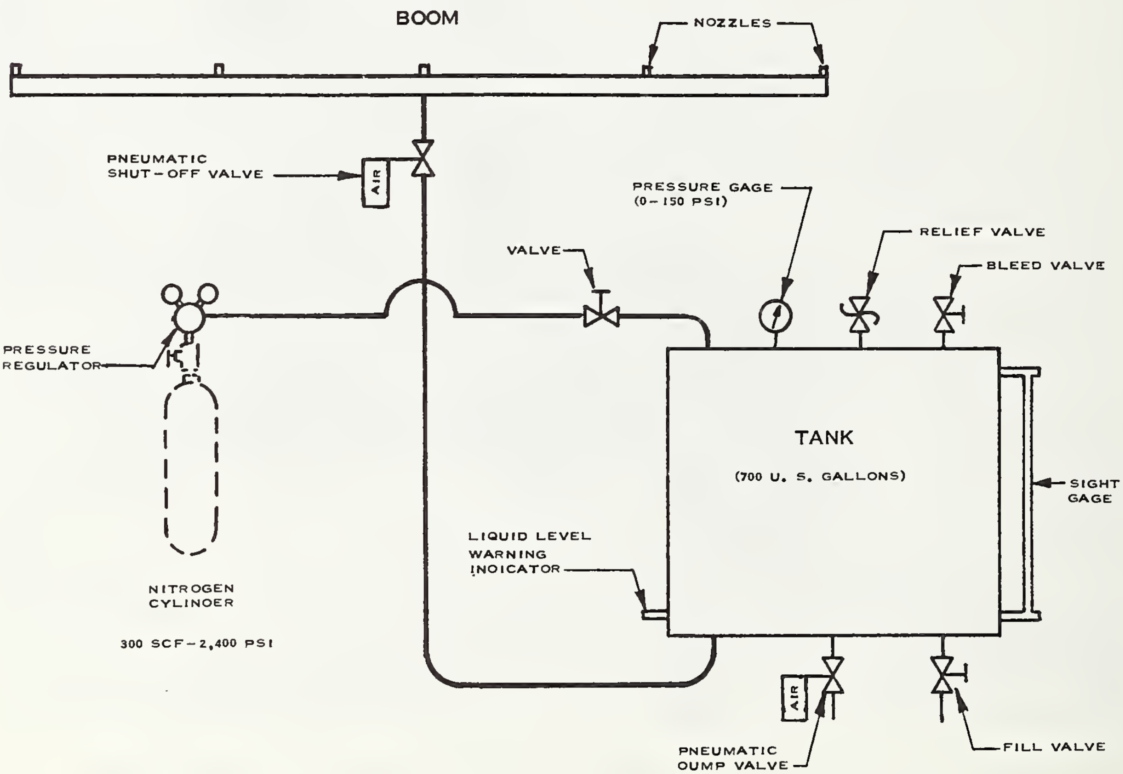

Figure 6.—Simplified schematic diagram of nitrogen-pressurized spray system.

To operate the spray system, the pilot or co-pilot must actuate the master switch to supply electric power to the control panel. An amber light indicates when the power is on. To release insecticide, the pilot moves the spray switch to the "on" position. This opens the pneumatic tank-to-boom valve (fig. 7), and the tank pressure forces insecticide through the boom and out of the spray nozzles. When the spray run has been completed, the pilot closes the tank-to-boom valve by moving the spray switch to "off." When the tank is empty, a red "level" light comes on.

Two full 300 scf cylinders of nitrogen will expel one full tank of insecticide. The nitrogen cylinder that actuates the valves must be replaced when its regulator reads 500 psi or less.

If an in-flight emergency occurs, the load can be jettisoned by actuating the "dump" switch on the control panel. The valves are triggered electrically, or in case of an electrical failure, by a pull cable in the cockpit.

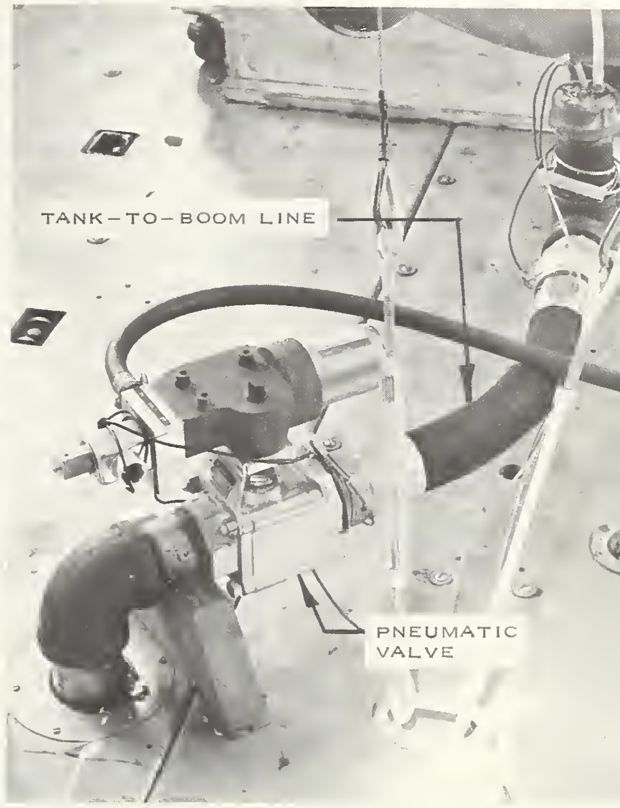

Figure 7.—Pneumatic valve in tank-to-boom line.

Nitrogen System.—In April 1972, the spray system performance was evaluated by the U.S. Army Deseret Test Center at Dugway, Utah. The tank was filled with a Zectran formulation approved for Forest Service use, tinted with red dye to facilitate droplet analysis. Booms were fitted with 104 No. 8015 nozzles (Spraying Systems Co.). Droplets were collected for analysis on spray assessment cards. Results are shown in table 1.

During the crosswind flight, 125 petri dishes, each holding 10 spruce budworm, were spaced within the test grid. Budworm mortality was 100 percent within a swath width of 950 feet. Effective swath width of the deposition pattern was based on the average width of that area within the pattern in which 100 percent spruce budworm larvae mortality was obtained.

Nitrogen-Freon System.—Common household aerosol products are about 85 percent by weight atomizing fluid, which is expensive. To minimize the amount of atomizing fluid required, the Center experimented extensively with various nozzles and ratios of insecticide and one atomizing fluid, Freon 12. A 1:1 ratio (by weight) of Freon 12 to insecticide propelled through a Spraying Systems TX-26 nozzle gave the best performance.

Although the Freon alone will propel the insecticide from the tank, as it does in common "bug bombs," large droplets will be produced. As the tank is emptied, pressure falls too low to keep the Freon 12 in solution (70 psi at 70°F), and it vaporizes in the tank, resulting in progressively less Freon being carried in solution with the insecticide to the nozzles. Nitrogen is metered into the tank at 75 psi to keep the Freon in solution until it reaches the nozzle expansion chamber.

Table 1.—*Performance characteristics*

Conventional Insecticide Formulations

Flight direction	Wind speed	Alti-tude	Indicated air speed	Flow rate	Effective swath width	Droplet size
	Mph	Feet	Knots	Gallons per minute	Feet	Microns (mmd)
Into wind	3.4	150	128	150	900	120± 10
Into wind	4.5	300	128	150	1200	120± 10
Slightly crosswind	4.9	150	128	150	900	120± 10

As shown in figure 8, the insecticide solution enters the expansion chamber of the TX-26 nozzle through metering passages. The pressure in the expansion chamber is much lower than the vapor pressure of the Freon 12, which flashes into a vapor and flows through the exit orifice at high velocity. As the solution leaves the orifice, the Freon 12 continues to expand at high velocity and breaks the insecticide into fine droplets. Droplets collected in laboratory tests and in field evaluations averaged 60 microns mmd and the largest droplets were 120 mmd. When the boom is fitted with 250 TX-26 nozzles, the maximum flow rate is 90 gpm of solution, of which 52 gpm is insecticide and carrier and 38 gpm is atomizing fluid. For an equal mixture by weight of insecticide solution and atomizing fluid, the 700 gallon tank would contain 405 gallons (58 percent) insecticide solution and 295 gallons (42 percent) of Freon 12.

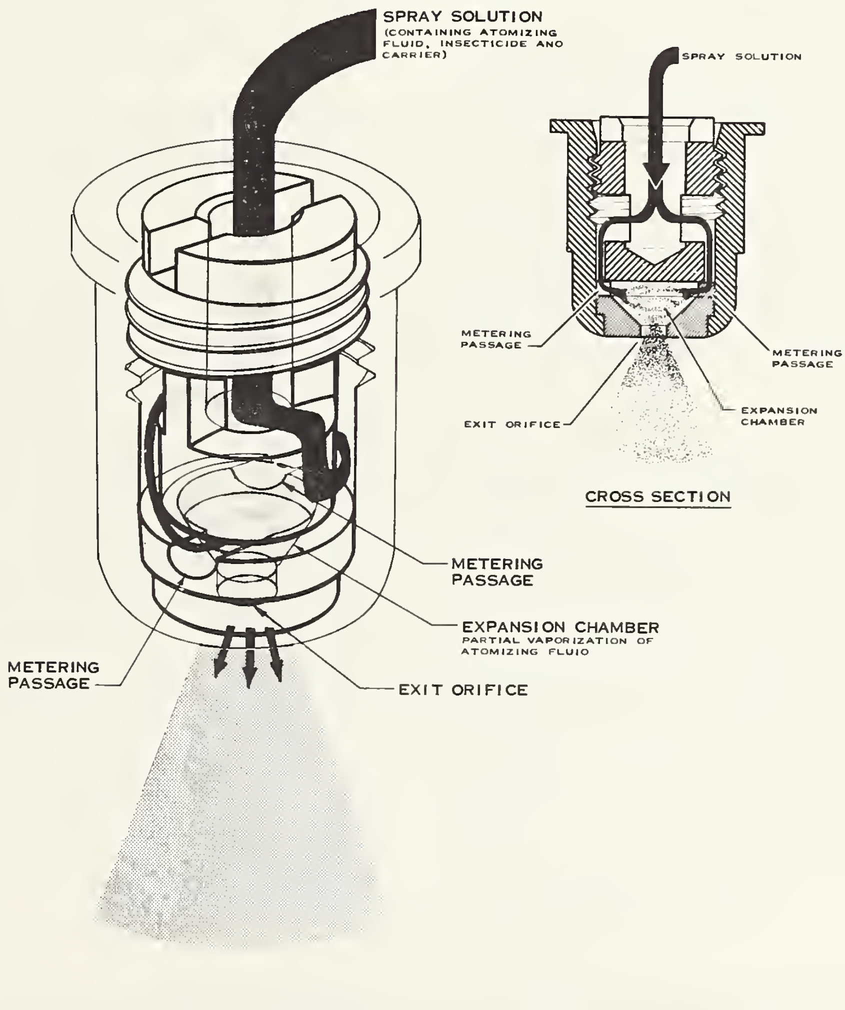

Figure 8.—Nozzle with expansion chamber for producing aerosol.

Airplane.—The airplane equipped with 104 number 8015 nozzles with the tank empty and a gross weight of 23,000 lb was tested for single engine performance. It maintained level flight on one engine at an indicated airspeed (IAS) of 85 mph with a power setting providing 640 bhp. With an increased power setting providing 830 bhp, the airplane climbed from a 5,500 foot pressure altitude to a 6,700 foot pressure altitude on one engine at 240 feet per minute at an IAS of 80 mph. Temperature was not recorded so density altitude was not determined. However, the flight was made during early morning under conditions typical of spraying projects.

To determine approximate horsepower consumed by the weight of the insecticide solution, the spray tank was filled with water (6,145 lb instead of 6,500 lb for insecticide) and the airplane was flown at a specific airspeed and density altitude. The water was released through the dump system and power settings adjusted to maintain previous airspeed at the same density altitude. About 200 bhp were required to carry the 6,145 lb of water.

The airplane was also flown with and without the boom. The spray system boom consumed 260 bhp at 150 mph IAS and 5,000 feet density altitude.

Figure 9.—C-47 applying insecticide on budworm infestation.

FIELD USE

The nitrogen-pressurized spray system has been used on pilot tests against the spruce budworm (*Choristoneura* sp.) in Montana and Idaho (fig. 9).

Nitrogen-Freon System.—In 1968, a pilot test was conducted on two test plots totalling 2,500 acres in the Blackfoot River drainage of western Montana. This was done in cooperation with the Northern Region Division of State and Private Forestry, and the Insecticide Evaluation Project (IEP), Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.[4] The purpose of the test was to determine effectiveness of the carbamate insecticide Zectran applied in extremely small droplets and low-volume dosages. The tank was loaded with 230 pounds of Zectran in a solution of 406 gallons of Dowanol-TPM[5] and 294 gallons of Freon 12. The Zectran was applied at the rate of 1 ounce (6 percent by volume) in 1 pint of Dowanol-TPM carrier, per acre. Droplets were no larger than 120 microns with an mmd of 60 microns. The spray system performed satisfactorily.

In 1969, two test plots on the Nezperce National Forest totalling 4,000 acres were sprayed with a solution of Zectran and Dowanol TPM atomized by Freon 12.[6] One test plot was sprayed at the rate of 0.15 lbs of Zectran in 0.5 gallons of Dowanol TPM carrier per acre. Another plot was sprayed twice — 24 hours between applications — at the rate of 0.075 lbs of Zectran in 0.5 gallons of carrier per acre. The spray system met requirements established by the project managers.

Nitrogen System.—In 1971, two C-47 airplanes fitted with the nitrogen-pressurized spray system were used in a pilot test of Zectran against the spruce budworm on the Nezperce Forest.[7] The insecticide was applied at the rate of .15 lb Zectran in 1 gallon of Kerosene per acre. No atomizing fluid was used. Spray booms on the two airplanes were fitted respectively with 103 and 104 No. 8015 nozzles. Spraying was done at a ground speed of 150 miles per hour, releasing 152 gallons per minute. A total of 9,000 acres was sprayed. Droplets collected on the ground measured 113.7 microns mmd. The spray systems again performed satisfactorily.

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4 McGregor, Mark D., and Jerald E. Dewey, 1969. Zectran pilot test to control spruce budworm Belmont and Chamberlain Creeks, Blackfoot River drainage, Montana. 1968. U.S. Department of Agriculture, Forest Service, Division of State and Private Forestry, Missoula, Montana.

5 Dowanol-TPM, Tripropylene Glycol Methyl Ether (CH_3-O-C_3H_6-O-C_3H_6-O-C_3H_6-OH) Dow Chemical Co., Midland, Mich.

6 Anonymous, 1969. Minutes 1969 Zectran pilot test analysis, Northern Region, U.S. Department of Agriculture, Forest Service, Missoula, Montana.

7 Dewey, Jerald E. et al, 1971. The 1971 Western Spruce Budworm Pilot Test — Nezperce National Forest and State of Idaho Lands. U.S. Department of Agriculture, Forest Service, Division of State and Private Forestry, Missoula, Montana.

CONCLUSIONS

A nitrogen-pressurized spray system for C-47 airplanes has been developed. The system is operated by using gaseous nitrogen to expel from the spray tank either (1) a conventional insecticide solution, which emerges with a droplet spectrum having a mass median diameter (mmd) of 120 microns; or (2) a solution 50 percent insecticide and 50 percent Freon 12, which emerges with a droplet spectrum having a mmd of 60 microns. It offers the following advantages:

1. **Versatility.**—The system has been used to apply insecticides in fine droplets (60 microns mmd) at volumes as low as one pint of insecticide solution per acre. It has also been used to apply insecticides in large droplets (120 microns mmd) at one gallon of solution per acre.

2. **Reliability.**—Utilizing nitrogen to propel the insecticide from the tank rather than a pump driven by a hydraulic motor of a gasoline engine has reduced the danger of leaks, gasoline fumes, and malfunctions. Properly installed, the nitrogen-pressurized system is clean, safe, and easy to operate.

3. **Airplane Performance.**—With insecticide dumped, a C-47 airplane can maintain altitude with one engine operating. The C-47 can be flown from back country airstrips and is considered excellent for low-level mountain flying.

4. **Availability.**—Most parts are stock items or can be readily fabricated, except for the tank. The tank can be built by metal fabricators who build aluminum pressure vessels. Cost of the system is about $10,000. This Center will supply additional information on request.

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